Annual Progress Report:

BENTHIC MONITORING PROJECT FOR THE MOLLIE BEATTIE COASTAL HABITAT COMMUNITY

By:

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Introduction

The construction of Packery Channel began in October 2003 to promote exchange between Corpus Christi Bay and the Gulf of Mexico. Packery Channel is part of a complex of storm washoverh channels which have opened intermittently during the passage of large storms and strong north fronts (Brown and Militello 1996). However, since dredging of the Aransas Pass inlet began in 1912, water diversion to Aransas Pass has in part caused Packery Channel to remain closed (Kraus and Heilman 1996).

One of the major concerns of opening the channel is the potential impact on the bird community of Mollie Beattie Coastal Habitat Community, an area adjacent to Packery Channel. Because benthos is a principal food item of birds, it is important to determine any effects of the channel on the benthic system. Benthic infauna are often used as ecological indicators in applied studies because they are relatively short-lived and fixed in space. This means they are useful for integrating environmental changes over time.

There are two objectives of the present study. The first objective is to assess the effect of the Packery Channel construction project on benthic infauna biomass, abundance, and diversity. The second objective is to assess the response of estuarine dependent species to construction. Packery Channel was unintentionally opened to the Gulf of Mexico on 21 July 2005. The opening was aided by storm surge from Hurricane Emily. Hurricane Emily was a Category 5 hurricane that occurred in the southern Gulf of Mexico and did not directly hit the study site. Packery Channel was officially opened in October 2006. Sampling was conducted prior to the channel opening and continued during and after channel construction. This report is the fourth annual progress report of the macrobenthic study.

Methods

A before-versus-after, control-versus-impact (BACI) experimental design (Green 1979) was chosen to determine effects of the project on benthos. Mollie Beattie Coastal Habitat Community (MBCHC) was chosen as an impact site because it is an area immediately adjacent to Packery Channel (Figure 1). Corpus Christi Pass was chosen as the reference site because it has a very similar habitat to the MBCHC site, but should not be directly affected by channel dredging (Figure 1). Corpus Christi Pass is approximately 3 km away from the Mollie Beattie site. The BACI design allows the establishment of two kinds of reference points to distinguish variability caused by the construction project from natural variability. Two shallow and two deep stations were sampled in both MBCHC and Corpus Christi Pass. The different depths were chosen to examine different depths where birds might forage. Macrofauna, hydrography and water chlorophyll samples were collected monthly while samples for sediment analysis were collected quarterly (Table 1).

Macrofauna. Macrofauna were sampled with a 6.7-cm diameter core tube (35.4 cm^2 area) and sectioned at depth intervals of 0 - 3 cm and 3 - 10 cm. Areas of seagrass were avoided to mitigate confounding effects. Duplicate samples were taken at each station and samples were preserved with 5% buffered formalin. In the laboratory, macrofauna were extracted using 0.5-mm sieves and identified to the lowest taxonomic level possible, usually the species level. Organisms from each sample were pooled into higher taxonomical categories (*Crustacea*, *Mollusca*, *Polychaeta*, and others) and dried for 24 h at 55˚C. The dried groups were then weighed to the nearest 0.01 mg to determine biomass. Mollusks were placed in 1 N HCl for a few minutes to dissolve carbonate shells, and washed before drying.

Community structure of macrofauna species was analyzed by nonmetric multidimensional scaling (MDS) and cluster analysis using a Bray-Curtis similarity matrix. Prior to analysis, the data was square root transformed. MDS was used to compare numbers of individuals of each species for each station-date combination. The distance between station-date combinations can be related to community similarities or differences between different stations. Cluster analysis determines how much each station-date combination resembles each other based on species abundances. The percent resemblance can then be displayed on the MDS plot to allow grouping of station-date combinations. The group average cluster mode was used for the cluster analysis.

Hydrography. Hydrographic characteristics of the water column were measured at each station during the sampling period. Measurements were taken at the surface and near the bottom using a YSI 6600 multiparameter instrument. Measurements were made of (accuracy and units): temperature (± 0.15 ˚C), pH (± 0.2 units), dissolved oxygen (± 0.2 mg/l), DO saturation (± 2%), specific conductivity (± 0.5% or ± 0.001 mS/cm), redox potential (± 0.05 mV), depth (± 0.02 m), and salinity (± 1% of reading or 0.1 ppt, whichever is greater) automatically corrected to 25˚C. We report salinity in parts per thousand (ppt).

YSI 6600 data sondes were also used to take continuous measurements to assess whether hydrographic conditions were changing in the MBCHC site relative to the reference site over time scales of less than one month. Data sondes were deployed at station M2 at the MBCHC site and at station R4 at the reference site. These two stations were both approximately 1 m deep relative to mean sea level. The data sondes were attached to PVC poles using hose clamps, with the sensors located at a mean depth of 0.5 meters. Although several water quality variables were measured, only salinity and temperature are reported in this study. Data sondes were deployed for four weeks in June and July 2005 (before Packery Channel opened), for three weeks in August, and 16 days in September 2005. Datasondes were replaced every 7 to 12 days to avoid fouling of the sensors. Measurements were taken every 15 minutes while data sondes were deployed.

Water level and tidal flow data were also obtained from the Texas Coastal Ocean Observation Network (TCOON, http://lighthouse.tamucc.edu). Water level was compared in the Gulf of Mexico at Bob Hall Pier with the water level at the Laguna Madre end of Packery Channel (Figure 1). Bob Hall Pier is four kilometers southwest of the Packery Channel entrance to the Gulf of Mexico. Water flow was measured by acoustic doppler current profilers (ADCPs), which were situated next to the Packery Channel water level recorder and also along Packery

Channel closer to the Gulf of Mexico (Figure 1). Flow measurements were recorded every thirty minutes. Data records were incomplete before October 2005 and after November 2005 so only data from these two months were analyzed. This period was after the opening of Packery Channel.

Nutrient analysis was conducted quarterly for silicate, phosphate, nitrate and nitrite combined and ammonium concentrations. Nutrient samples were taken at the surface by hand and immediately chilled with ice and placed in the dark. A flow injected Lachet Quikchem 8000 automated nutrient analyzer was used to determine nutrient concentrations. This method used the basic chemistry outlined by Parsons et al (1984). Surface chlorophyll a (Chl a) samples were taken monthly. Samples were filtered in the field on glass microfiber filters and chilled with ice. The chlorophyll was then extracted from the filter with methanol over a period of 12 - 14 hrs. at < 0°C. Samples were then analyzed using a TD-700 fluorometer.

Sediment analysis. Sediment analyses were conducted quarterly for grain size. Sediment grain size analysis was measured as percent contribution of grain size by weight. Grain size was classified by four components following standard geologic procedures (Folk, 1964): rubble (e.g., shell hash), sand, silt, and clay. For analysis, a 20 cm^3 sediment sample was mixed with 50 ml of hydrogen peroxide and 75 ml of deionized water to digest organic material in the sample. The sample was then wet sieved through a 62 μm mesh stainless steel screen using a vacuum pump and a Millipore Hydrosol SST filter holder to separate rubble and sand from silt and clay. After drying, the rubble and sand were separated on a 125 μm screen. The silt and clay fractions were determined using settling rate velocity measurements and pipette analysis.

Results

Macrofauna

Macrofauna samples were taken in twenty-one consecutive months (November 2003 to July 2005 before Packery Channel was opened (Table 1). All of the sampling dates from before the opening of Packery Channel were analyzed for this report. Data were collected during three separate five-month long sampling periods after the opening of Packery Channel: August to December 2005, November 2006 to March 2007 and November 2007 to March 2008.

Overall, a greater difference in macrofauna community structure was observed between bottom depths than when comparing samples from before and after Packery Channel was opened or when comparing samples from different sampling sites (Figure 2). Almost all date-stations of community structure were significantly different from each other. Some differences in macrofaunal community structure were observed before and after the opening of Packery Channel at the shallow sampling stations; however, this difference was observed at both MBCHC and reference stations.

Total macrofauna abundance followed a seasonal cycle with maxima occurring in the winter (approximately November - March; Figures 3 and 4). Total abundance was highest at the beginning of the sampling period between January and March 2004. Total abundance was higher at MBCHC (10,100 n m^{-2}) than at the reference site (7,500 n m^{-2}). Total macrofauna biomass also followed a seasonal trend, with minima occurring between October and January (Figures 5 and 6). This seasonal cycle was most obvious in the shallow stations of each site. No peaks in total biomass have been recorded after the opening of Packery Channel. Both MBCHC and the reference site consist of diverse macrofaunal assemblages with at least one hundred and thirty species found in each site (Table 2). The total number of species found at MBCHC was 138, compared to 130 species found at the reference site. Peaks in N1 diversity occurred in winter 2003 - 2004 and spring 2005 (Figures 7 and 8). There was no consistent difference in diversity between MBCHC and the reference site before the opening of Packery Channel. However, diversity has been higher at the reference site than MBCHC since January 2006.

Before the opening of Packery Channel, the tanaidacean *Leptochelia rapax* was the dominant species overall (11 %) followed by unidentified oligochaetes (8 %), and then polychaetes *Prionospio heterobranchia* (8 %), *Sphaerosyllis* sp. A (7 %), and the amphipod *Ampelisca abdita* (6 %) (Table 3). These most abundant five species made up close to 40% of the total abundance before the opening of Packery Channel. The dominance of *L. rapax* is due to a population explosion that occurred between January and March 2004 at the shallow MBCHC sites (Figure 4). At the peak of this population explosion, *L. rapax* occurred in densities as high as 53,000 n m^{-2} in individual samples. *L. rapax* was not common after this peak in March 2004 (< 1,500 n m^{-2} in individual samples). Five more species were found in MBCHC than at the reference site before the opening of Packery Channel. Total abundance before the opening of Packery Channel was 10,500 n m^{-2} in MBCHC, compared with 7,700 n m^{-2} at the reference site.

After the opening of Packery Channel, the polychaetes *Streblospio benedicti* and *Prionospio heterobranchia* were the dominant species (16% and 14 % respectively) followed by unidentified oligochaetes (13 %) and the polychaetes *Mediomastus ambiseta* and *Sphaerosyllis* sp. A (each 5 %) (Table 4). These five most abundant organisms made up 53% of the total abundance found after the opening of Packery Channel. Mean total abundance was greater at MBCHC (9,500 n m^{-2}) than the reference site (7,800 n m^{-2}) after the opening of Packery Channel; however, the magnitude of the observed difference in abundance between the MBCHC and reference sites was greater before the opening of Packery Channel.

The dominant species were different at the impact (MBCHC) and reference (Corpus Christi Pass) sites. Total abundance was higher at MBCHC (10,100 m^{-2}) than at Corpus Christi Pass (7,500 m^{-2}). The differences in macrofauna abundance, biomass and diversity between control (Corpus Christi Pass) and impact (MBCHC) sites are complex (Figures 4 to 8), making an assessment of the impacts of the construction of Packery Channel on benthic macrofauna difficult. Impacts will be more fully assessed after the completion of sampling in March 2009.

Hydrography

Salinity values were lower at both reference and impact sites before the opening of Packery Channel than during the first year after the channel was open (Figure 9). Salinity started to rise at both stations in March 2005 (before the opening of Packery Channel) and peaked above 45 ppt in September 2006 (53.9 and 46.7 ppt at the reference site and MBCHC respectively) before declining to below 35 ppt at both sites from January 2007 onward. With a few exceptions, mean salinities for the MBCHC and the reference sites were similar to each other for the pre - channel opening portion of the study period. The difference in salinity between the impact and reference sites was larger after the opening of Packery Channel, although salinity was not consistently higher at either site.

Salinity was more variable than temperature between continuous datasonde sampling periods (Figures 10 to 12). The first period in June - July 2005 had no diurnal fluctuations in salinity but had two maxima and minima throughout the period. The minima were around June 14 and 30, while the maxima occurred around June 24 and July 6. In June - July, salinity was generally 2 - 4 ppt higher at the MBCHC site than the reference site. Temperature followed a diurnal pattern with peaks mostly occurring around 5 - 6 p.m. and troughs occurring around 6 a.m. Peak daily temperatures were also commonly 0.5 - 1°C warmer at the MBCHC site. Water levels in Packery Channel were higher than mean sea level for all but the last week of the June - July period. Diurnal tidal fluctuations were small at Bob Hall Pier and Packery Channel during 3-day periods in mid- and late June.

Salinity increased from 42 to 48 ppt between August 6 and 24 at the reference site (Figure 10). The MBCHC site showed a similar increase from 39 to 42 ppt during the period from August 6-16, but salinity at MBCHC declined to 40 ppt during the interval between August 16-24. The original data sondes deployed on August 6 were replaced on August 16. It appears that the data were more variable from this point onward at both sites because of equipment malfunction, even though the data sondes read manufactured salinity standards correctly in the laboratory when tested after their retrieval. It is suspected that some chemical or biological agent interfered with the conductivity sensor during this latter period of deployment. The source of the problem could have been small gobies that are sometimes found inhabiting the sensor casings.

Temperature in August again followed a diurnal pattern, however more differences were observed in daily minima and maxima between sites than in the June-July period. Water level was also consistently lower during august than during most of the June-July sampling period or during the September sampling period. Tidal fluctuations were smallest between August 8 and 11 and between August 21 to 23. At these times only, temperature was greater at the reference site than at the MBCHC site.

In September 2005, salinity at the MBCHC site followed an almost diurnal pattern (Figure 12). The periodicity of this pattern was approximately 24 to 26 hours, depending on the date. Typical fluctuations for salinity in each 24 to 26 hour period were 3 - 7 ppt. Salinity at the reference site did not fluctuate as much as at the MBCHC site. At the reference site salinity steadily increased from close to 34 ppt on September 13 to just less than 40 ppt on September 28. Salinity data from the data sondes deployed at the reference site for the September study period did not match discrete sample values taken at the time of data sonde retrieval. This mismatch was a constant value for each of the two sondes deployed; data from this period were adjusted by adding the difference between the simultaneous discrete readings and the continuous readings to all salinity values in the September study period. Temperature maxima in September 2005 were consistently 1°C lower at the reference site than the MBCHC site, except for the period between September 19 and 21 when the reference temperatures were similar or higher. Water level was consistently higher in September than the June - July and August monitoring periods at both Bob Hall Pier and Packery Channel. An increase in water level on 24 September was created from storm surge and meteorological forcing associated with the approach of Hurricane Rita, which eventually made landfall at the Texas - Louisiana border. No rainfall associated with Hurricane Rita was recorded in the Corpus Christi area.

Tidal flow through Packery Channel was 3 - 5 times higher at the sampling station 2 km from the Gulf than adjacent to the Laguna Madre (5 km from Gulf) in October and November 2005. The median flow at the gulfward measuring station was 0.27 m s^{-1} with an inter-quartile range of 0.11 - 0.47 m s^{-1}. The median flow at the station adjacent to the Laguna Madre was 0.06 m s^{-1}, with an inter-quartile range of 0.03 - 0.11 m s^{-1}. The tidal flow cycle at the Gulf-ward station strongly resembled the tidal cycle in the Gulf of Mexico with peaks in flow occurring simultaneously with high and low tides. The diurnal and semidiurnal tidal flow cycles were less pronounced closer to the Laguna Madre than near the Gulf.

Discussion

The results of the macrofauna component of this current study must be interpreted conservatively because the dataset is unbalanced. There were twenty-one consecutive months sampled prior to the channel opening, but there have been only thirteen samples from three, five-month periods taken after the opening of Packery Channel. The macrofauna abundance and biomass data exhibit seasonal changes, and the analyses performed (e.g. dominance calculations) do not compensate for the seasonal changes.

Four of the six most abundant species of macrobenthos were the same before and after the opening of Packery Channel, although their relative abundance varied (Tables 3 and 4). Before the opening of Packery Channel, the tanaidacean *Leptochelia rapax* (also called *Hargeria rapax*; García-Madrigal, 2005) was the most abundant species. After Packery Channel opened, the polychaetes *Prionospio* heterobranchia and Streblospio *benedicti* were co-dominants.

The presence of *L. rapax* as the dominant species before Packery Channel opened can likely be attributed to a population boom that occurred between January and March 2004. *L. rapax* densities reached 22,000 individuals per m^{-2} in February 2004. Similar *L. rapax* densities for periods of 6 - 8 weeks have been documented to occur in winter months in Georgia, USA, after reproduction peaks in autumn (Kneib, 1992). *L. rapax* population fluctuations are thought to be related to predation and reproduction (Kneib, 1992). *S. benedicti*, the most dominant species after the opening of Packery Channel, is a pioneer species indicative of disturbed environments. While the high relative abundance of this species may be related to the opening of Packery Chanel, it might also reflect inconsistent sampling or a seasonal abundance cycle.

The sampling period change from monthly before Packery Channel was opened to only five months of the year after Packery Channel opened affects the interpretation of the time series analyses and makes it difficult to compare total abundance, biomass and diversity over time (Figures 3 to 8). Seasonal cycles in total macrofaunal abundance and biomass that are apparent before the opening of Packery Channel are not obvious after the opening of Packery Channel. Before the channel was opened, biomass minima and abundance maxima occur approximately around the winter months. Peaks in abundance and low biomass values were observed after the opening of Packery Channel when macrofaunal samples were taken monthly between November and March only. However, seasonal maxima and minima of abundance and biomass before the opening were not in the same months every year. Because of these differences in timing of seasonal minima and maxima, it is difficult to determine whether any differences in abundance and biomass after July 2005 can be attributed to the opening of Packery Channel, or attributed to natural variations in the seasonal cycles.

The change in sampling frequency before and after the opening of Packery Channel also affects the ability to detect change in total diversity over time between the MBCHC and the reference site in Corpus Christi Pass. Diversity at the reference site has been consistently higher than at MBCHC since five months after the opening of Packery Channel (Figures 7 and 8). Whereas before the opening of Packery Channel, there was no consistent difference in diversity between sites. Further sampling over time, or processing samples taken between April and October from the past, will allow us to determine whether this is a permanent change or not.

Monthly salinity was similar at both the impact and reference sites before the opening of Packery Channel, but a greater difference was observed between the sites after the opening. The salinity was generally lower at MBCHC when salinity values at both sites were above 33 ppt (Figure 9). USACE (2003) predicted that maximum salinities would decrease by 3 - 5 ppt around MBCHC after the opening of Packery Channel. This prediction can be compared with post-channel opening measurements in this study because high salinities at both sites did occur in the sampling period after Packery Channel opened. The highest salinities in the post-channel opening study period occurred between August 2005 and December 2006. During this period, the average salinity in MBCHC was 38.9 ppt, whereas the mean salinity in the reference site was 41.2 ppt. This difference of 2.2 ppt is lower than what USACE (2003) predicted. The highest salinities in Corpus Christi Bay usually occur between July and October (Applebaum *et al.*, 2005). On the three occasions when salinity at the reference site was above 35 ppt before the channel opened, the differences in mean salinity between the two sites were less than 1 ppt. Considerable variability in salinity in Corpus Christi Bay was recorded even before Packery Channel was opened (Applebaum *et al.*, 2005); given this variability, it is possible that the difference observed between the impact and reference sites after the opening primarily reflect natural variation.

The salinities between June 2005 and December 2006 were consistently the highest over the entire study period. This period of high salinity is probably the result of greater environmental variation, including a six-month drought between December 2005 and June 2006, rather than from the opening of Packery Channel. It is uncertain whether a drought occurring before the opening of Packery Channel would have resulted in the same 2.2 ppt salinity difference between the impact and reference sites. Similarly high salinities are seen from July 2008 through to September 2008, indicating that long-term variability is a greater factor in causing salinity differences between the sites than change due to the opening of Packery Channel.

The largest difference in salinity observed at the impact and reference sites is the diurnal fluctuation that occurred only in MBCHC between September 13 and 28 (Figure 4). This fluctuation does not occur at MBCHC in June, July, or August or at the reference site at any time period. The fluctuation probably did not occur in the August sampling period because the water level in the Gulf of Mexico was lower. Elevated water levels theoretically should increase hydraulic head and therefore tidal inflow through Packery Channel into MBCHC. Thus, an increase in tidal mixing caused by elevated water levels caused diurnal salinity fluctuations after the opening of Packery Channel in MBCHC.

Further evidence for mixing of Gulf of Mexico waters with waters in MBCHC is the 3 -5 fold decrease in flow from the gulfward flow measuring station to the measuring station at the Laguna Madre end of Packery Channel (stations locations shown in Figure 1). Because the cross sectional area of Packery Channel is not very different between the two stations, some tidal flow must be diverted in and out of MBCHC. Since the channel opening, water has been flowing through several newly formed channels on the tidal flats on the northeast side of Packery Channel.

Salinity was likely the primary factor in the changing macrofauna communities of another artificial inlet on the Gulf coast. In a study in Apalachicola Bay, Florida, an increase in salinity from artificially opening Sikes Cut was caused by increasing the exchange between Bay waters and the Gulf of Mexico and diverting freshwater inflow through the cut (Zeh, 1980; Huang *et al.*, 2002). This increase in salinity allowed a population increase in euryhaline oyster predators, including the gastropod *Thais haemastoma* and the crab *Menippe mercenaria* (Menzel *et al.*, 1956). The increase in predator abundance was correlated with a decrease in oyster productions after the opening of Sikes Cut (Menzel *et al.*, 1956). Although oyster beds were not included in the sampling design of the present MBCHC study, this result is still relevant to the present study. So far, no offshore or euryhaline species have been observed in MBCHC, likely because Corpus Christi Bay, the Laguna Madre and MBCHC have much higher salinities than euryhaline species can tolerate (Orlando *et al.*, 1998; Niu *et al.*, 1998). Because salinities were relatively high for the period beginning a few months before Packery Channel opened through l December 2006, the effects of Packery Channel on benthic community structure after a large period of lower salinity are yet to be determined.

Overall, Packery Channel may have affected the salinity of MBCHC by introducing a diurnal fluctuation when water levels are high and by possibly lowering salinity in MBCHC when salinities are high in Corpus Christi Bay. The same salinity changes were not observed at reference site. Flow decreases along a gradient moving up Packery Channel away from the Gulf of Mexico, which suggests that the tidal flow spills into MBCHC. The small change in hydrography in MBCHC has had little initial impact on macrobenthic communities, probably because MBCHC was already functioning as marine in terms of salinity. Future long-term changes in hydrography or sediment structure could change the macrofaunal community. The greatest change may be seen when salinity differences are normally greatest between MBCHC and the Gulf of Mexico (i.e., after periods of high rainfall and low evaporation). The completion of this project, which includes additional sampling until March 2009, will be key in determining whether there is any long-term macrofaunal change in MBCHC.

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Table 1. Dates of samples taken. X = sample taken and processed. * = sample taken but not processed. Dotted line marks time when Packery Channel opened (21 July 2005)

Sample Date	Hydrography	Macrofauna	Sediment Grain Size	Chlorophyll a	Nutrients	Sediment Porosity	Sediment chemistry
04Nov2003	X	X	X	X		X	X
01Dec2003	X	X		X			
13Jan2004	X	X	X	X		X	X
05Feb2004	X	X		X			
02Mar2004	X	X		X			
02Apr2004	X	X	X	X	X	X	X
21May2004	X	X		X			
24Jun2004	X	X		X			
23Jul2004	X	X	X	X	X	X	X
27Aug2004	X	X		X			
23Sep2004	X	X		X			
15Oct2004	X	X	X	X	X	X	X
08Nov2004	X	X		X			
09Dec2004	X	X		X			
07Jan2005	X	X	X	X		X	X
08Feb2005	X	X		X			
08Mar2005	X	X		X			
11Apr2005	X	X	X	X	X	X	X
09May2005	X	X		X			
08Jun2005	X	X		X			
11Jul2005	X	X	X	X	X	X	X
06Aug2005	X	X		X			
13Sep2005	X	X		X			
07Oct2005	X	X	X	X	X	X	X
07Nov2005	X	X		X			
07Dec2005	X	X		X			
09Jan2006	X		X	X	X	X	X
10Feb2006	X			X			
07Mar2006	X			X			
07Apr2006	X		X	X	X	X	X
10May2006	X			X			
09Jun2006	X			X			
24Jul2006	X		X	X	X	X	X
18Aug2006	X			X			
07Sep2006	X			X			
04Oct2006	X		X	X	X	X	X
02Nov2006	X	X		X			
04Dec2006	X	X		X			
03Jan2007	X	X	X	X	X	X	X
01Feb2007	X	X		X			
01Mar2007	X	X		X			
06Apr2007	X		X	X	X	X	X
03May2007	X			X			
01Jun2007	X			X			

Sample Date	Hydrograph y	Macrofauna	Sediment Grain Size	Chlorophyll a	Nutrients	Sediment Porosity	Sediment chemistry
13Jul2007	X		X	X	X	X	X
01Aug2007	X			X			
05Sep2007	X			X			
24Oct2007	X	X	X	X	X	X	X
09Nov2007	X	X		X			
05Dec2007	X	X		X			
10Jan2008	X		X	X	X	X	X
07Feb2008	X			X			
05Mar2008	X			X			
04Apr2008	X		X	X		X	X
06May2008	X			X			
01Jul2008	X		X	X		X	
04Aug2008	X		X			X	
08Sep2008	X						

Table 2. Mean species dominance over the entire sampling period.

Species	Abundance (n m^{-2})			Percentage	
	Mollie Beattie	Reference	Mean	Mean	Cumulative
Prionospio heterobranchia	509	1255	882	10.04	10.04
Oligochaetes (unidentified)	935	803	869	9.90	19.94
Streblospio benedicti	1208	274	741	8.44	28.37
Leptochelia rapax	1350	20	685	7.80	36.18
Sphaerosyllis sp. A	790	267	529	6.02	42.20
Mediomastus ambiseta	671	267	469	5.34	47.53
Capitella capitata	622	166	394	4.48	52.02
Ampelisca abdita	324	354	339	3.86	55.88
Brania furcelligera	209	467	338	3.85	59.72
Tellina tampaensis	208	282	245	2.78	62.51
Axiothella mucosa	354	108	231	2.63	65.14
Haploscoloplos sp.	217	147	182	2.07	67.21
Laeonereis culveri	268	78	173	1.97	69.18
Branchioasychis americana	213	127	170	1.94	71.12
Syllis cornuta	105	216	161	1.83	72.94
Microphthalmus abberrans	22	282	152	1.73	74.67
Haploscoloplos foliosus	157	121	139	1.58	76.26
Nemertinea (unidentified)	86	176	131	1.49	77.75
Heteromastus filiformis	125	116	120	1.37	79.12
Cerithium lutosum	137	71	104	1.18	80.30
Grandidierella bonnieroides	117	86	101	1.15	81.45
Magelona pettiboneae	67	125	96	1.09	82.54
Ophryotrocha sp. (unidentified)	16	138	77	0.87	83.42
Anomalocardia auberiana	21	131	76	0.87	84.28
Corophium louisianum	150	1	76	0.86	85.15
Exogone sp.	69	80	75	0.85	85.99
Ostracoda (unidentified)	107	32	70	0.80	86.79
Eteone heteropoda	52	87	69	0.79	87.58
Spiorbis sp.	70	67	68	0.78	88.36
Anthozoa (unidentified)	25	101	63	0.72	89.08
Crepidula convexa	82	44	63	0.72	89.80
Melinna maculata	51	63	57	0.65	90.44
Laevicardium mortoni	7	87	47	0.53	90.98
Oxyurostylis sp.	55	25	40	0.46	91.43
Diastoma varium	46	32	39	0.45	91.88
Cymadusa compta	22	45	33	0.38	92.26
Tellina texana	34	23	29	0.33	92.59
Chone sp.	13	43	28	0.32	92.90
Turbonilla sp.	31	20	26	0.29	93.19

Species	Abundance (n m^{-2})			Percentage	
	Mollie Beattie	Reference	Mean	Mean	Cumulative
Spio pettiboneae	15	33	24	0.27	93.47
Turbellaria (unidentified)	18	30	24	0.27	93.74
Glycinde solitaria	23	24	23	0.27	94.00
Axiothells sp. A	16	30	23	0.26	94.27
Neritina virginea	46	0	23	0.26	94.53
Molgula manhattensis	5	40	22	0.25	94.78
Polydora ligni	6	35	21	0.24	95.02
Caprellidae sp.	26	16	21	0.24	95.26
Haploscoloplos fragilis	26	14	20	0.23	95.48
Amygdalum papyrium	15	24	19	0.22	95.70
Gyptis vittata	15	22	18	0.21	95.91
Acteocina canaliculata	22	8	15	0.17	96.08
Scolelepis texana	11	19	15	0.17	96.26
Diopatra cuprea	13	16	14	0.16	96.42
Maldanidae (unidentified)	13	16	14	0.16	96.58
Microprotopus spp.	23	4	14	0.15	96.73
Crepidula plana	0	26	13	0.15	96.88
Fabriciola trilobata	13	11	12	0.14	97.02
Syllis gracilis	2	22	12	0.14	97.15
Diastylis sp.	18	5	11	0.13	97.28
Xenanthura brevitelson	2	19	10	0.12	97.40
Gastropoda (unidentified)	8	13	10	0.12	97.52
Edotea montosa	6	14	10	0.11	97.63
Listriella barnardi	15	2	8	0.10	97.73
Gammarus mucronatus	10	4	7	0.08	97.81
Naineris sp. A	2	13	7	0.08	97.90
Erichsonella attenuata	9	5	7	0.08	97.98
Cerapus tubularis	4	9	7	0.08	98.06
Cymodoce faxoni	4	8	6	0.07	98.13
Pycnogonida (unidentified)	9	2	6	0.07	98.19
Hemicyclops sp.	3	7	5	0.06	98.25
Bivalvia (unidentified)	3	7	5	0.06	98.31
Arenicola cristata	2	8	5	0.06	98.37
Parahesione luteola	3	6	5	0.05	98.42
Scoloplos texana	7	2	5	0.05	98.48
Glyceridae (unidentified)	0	9	5	0.05	98.53
Pectinaria gouldii	5	3	4	0.05	98.58
Minuspio cirrifera	7	0	4	0.04	98.62
Scolelepis squamata	5	2	4	0.04	98.66
Euclymene sp. B	1	6	4	0.04	98.70

Species	Abundance ($n\ m^{-2}$)			Percentage	
	Mollie Beattie	Reference	Mean	Mean	Cumulative
Eulimostoma sp.	0	7	4	0.04	98.74
Nereidae (unidentified)	6	1	4	0.04	98.78
Eudorella sp.	6	1	4	0.04	98.82
Schizocardium sp.	6	0	3	0.04	98.86
Bulla striata	3	3	3	0.04	98.89
Schistomeringos rudolphi	0	6	3	0.04	98.93
Capitellidae (unidentified)	2	4	3	0.04	98.96
Clibanarius vittatus	5	0	3	0.03	98.99
Lyonsia hyalina floridana	3	2	3	0.03	99.02
Sarsiella zostericola	4	1	3	0.03	99.05
Sabella microphthalma	1	4	3	0.03	99.08
Batea catharinensis	5	0	3	0.03	99.11
Macroclymene sp. A	0	5	3	0.03	99.14
Vitrinella floridana	4	0	2	0.02	99.17
Macoma tenta	4	0	2	0.02	99.19
Argopecten irradians amplicostatus	2	2	2	0.02	99.22
Mysidopsis bahia	2	2	2	0.02	99.24
Sabellidae (unidentified)	1	3	2	0.02	99.27
Melita nitida	3	1	2	0.02	99.29
Pseudodiaptomus pelagicus	0	3	2	0.02	99.31
Mitrella lunata	3	0	2	0.02	99.33
Glycera americana	3	0	2	0.02	99.34
Callinectes sapidus	3	0	2	0.02	99.36
Potamilla cf. spathiferus	2	1	2	0.02	99.38
Callinectes similis	3	0	2	0.02	99.40
Amphiodia atra	3	0	2	0.02	99.42
Sayella crosseana	3	0	2	0.02	99.43
Armandia maculata	3	0	2	0.02	99.45
Sphaerosyllis erinaceus	2	1	2	0.02	99.47
Hippolyte zostericola	1	2	2	0.02	99.49
Ascidiacea (unidentified)	0	3	2	0.02	99.51
Scoloplos rubra	0	3	2	0.02	99.52
Nassarius acutus	2	0	1	0.01	99.54
Sigambra tentaculata	2	0	1	0.01	99.55
Henrya goldmoni	0	2	1	0.01	99.56
Podarke obscura	0	2	1	0.01	99.57
Echiuridae (unidentified)	2	0	1	0.01	99.58
Polydora sp.	0	2	1	0.01	99.60
Marphysa sanguinea	2	0	1	0.01	99.61
Bowmaniella sp.	2	0	1	0.01	99.62

Species	Abundance (n m^{-2})			Percentage	
	Mollie Beattie	Reference	Mean	Mean	Cumulative
Listriella clymenellae	2	0	1	0.01	99.63
Notomastus latericeus	1	1	1	0.01	99.64
Mysidopsis almyra	1	1	1	0.01	99.66
Holothuroidae (unidentified)	1	1	1	0.01	99.67
Polydora caulleryi	0	2	1	0.01	99.68
Potamilla reniformis	0	2	1	0.01	99.69
Odostomia sp.	1	0	1	0.01	99.70
Anadara transversa	1	0	1	0.01	99.70
Eurythoe sp.	1	0	1	0.01	99.71
Owenia fusiformis	1	0	1	0.01	99.72
Sipuncula (unidentified)	1	0	1	0.01	99.72
Pinnixa sp.	1	0	1	0.01	99.73
Erichthonias brasiliensis	1	0	1	0.01	99.74
Odostomia laevigata	0	1	1	0.01	99.74
Ensis minor	0	1	1	0.01	99.75
Pilargis berkelyae	0	1	1	0.01	99.75
Platynereis dumerilii	0	1	1	0.01	99.76
Spiochaetopterus costarum	0	1	1	0.01	99.77
Cyclopoida (unidentified)	0	1	1	0.01	99.77
Mysidopsis sp.	0	1	1	0.01	99.78
Mollusca (unidentified)	1	0	1	0.01	99.78
Odostomia canaliculata	1	0	1	0.01	99.79
Rictaxis punctostriatus	1	0	1	0.01	99.80
Cerithidea pliculosa	1	0	1	0.01	99.80
Caecum pulchellum	1	0	1	0.01	99.81
Melanella jamaicensis	1	0	1	0.01	99.81
Anachis semiplicata	1	0	1	0.01	99.82
Mulinia lateralis	1	0	1	0.01	99.83
Tellina sp.	1	0	1	0.01	99.83
Mercenaria campechiensis	1	0	1	0.01	99.84
Sigambra bassi	1	0	1	0.01	99.84
Neanthes succinea	1	0	1	0.01	99.85
Onuphis sp.	1	0	1	0.01	99.86
Capitellides jonesi	1	0	1	0.01	99.86
Pomatoceros americanus	1	0	1	0.01	99.87
Leptochela serratorbita	1	0	1	0.01	99.87
Leander tenuicornis	1	0	1	0.01	99.88
Callinectes sp.	1	0	1	0.01	99.89
Amphipoda (unidentified)	1	0	1	0.01	99.89
Nudibranchia (unidentified)	0	1	1	0.01	99.90

Species	Abundance (n m^{-2})			Percentage	
	Mollie Beattie	Reference	Mean	Mean	Cumulative
Polymesoda maritima	0	1	1	0.01	99.90
Aligena texasiana	0	1	1	0.01	99.91
Chione sp.	0	1	1	0.01	99.92
Polychaete juv. (unidentified)	0	1	1	0.01	99.92
Eumida sanguinea	0	1	1	0.01	99.93
Syllidae (unidentified)	0	1	1	0.01	99.93
Polydora websteri	0	1	1	0.01	99.94
Spio setosa	0	1	1	0.01	99.95
Spionidae (unidentified)	0	1	1	0.01	99.95
Cossura delta	0	1	1	0.01	99.96
Ampharetidae (unidentified)	0	1	1	0.01	99.96
Pista palmata	0	1	1	0.01	99.97
Serpulidae (unidentified)	0	1	1	0.01	99.98
Tozeuma carolinense	0	1	1	0.01	99.98
Neopanope texana	0	1	1	0.01	99.99
Amphilochus sp.	0	1	1	0.01	99.99
Allothyone mexicana	0	1	1	0.01	100.00
Total	10105	7457	8781	100.00	
Total Number of species	138	130	176		

Table 3. Mean abundances of dominant macrofauna species for sites over all dates and replicates when Packery Channel was closed (November 2003 to July 2005). Values are reported in individuals m^{-2}. Dominant species are defined by species with abundance over 1 %. MBCHC = Mollie Beattie Coastal Habitat Community.

Species Name	MBCHC	Reference	Mean	% of Mean Total	Cumulative %
Leptochelia rapax	1957	27	992	11.20	11.20
Oligochaetes (unidentified)	604	795	700	7.90	19.10
Prionospio heterobranchia	336	1048	692	7.81	26.91
Sphaerosyllis sp. A	905	292	599	6.76	33.67
Ampelisca abdita	486	517	501	5.66	39.33
Mediomastus ambiseta	638	329	484	5.46	44.79
Capitella capitata	734	169	452	5.10	49.89
Brania furcelligera	299	564	431	4.87	54.76
Streblospio benedicti	711	22	366	4.14	58.89
Axiothella mucosa	555	144	349	3.95	62.84
Haploscoloplos sp.	280	208	244	2.75	65.59
Tellina tampaensis	230	248	239	2.70	68.29
Microphthalmus abberrans	24	424	224	2.53	70.81
Branchioasychis americana	282	103	192	2.17	72.98
Laeonereis culveri	284	66	175	1.97	74.96
Heteromastus filiformis	159	164	161	1.82	76.78
Nemertinea (unidentified)	106	186	146	1.65	78.43
Grandidierella bonnieroides	172	91	132	1.49	79.91
Corophium louisianum	226	2	114	1.29	81.20
Magelona pettiboneae	88	127	107	1.21	82.41
Exogone sp.	110	96	103	1.16	83.57
Crepidula convexa	133	71	102	1.15	84.72
Ostracoda (unidentified)	154	41	97	1.10	85.82
Anthozoa (unidentified)	30	159	95	1.07	86.89
Dominant species	24	24	24	20.69	
Dominant abundance	9504	5891	7697	86.89	
Other species	79	74	92	79.31	
Total species	103	98	116	100	
Total abundance	10495	7223	8859	100	

Table 4. Mean abundances of dominant macrofauna species for sites over all dates and replicates when Packery Channel was open. Values are reported in individuals m^{-2}. Dominant species are defined by species with abundance over 1 %. MBCHC = Mollie Beattie Coastal Habitat Community.

Species Name	MBCHC	Reference	Mean	% of mean total	Cumulative %
Streblospio benedicti	2010	682	1346	15.58	15.58
Prionospio heterobranchia	788	1587	1188	13.75	29.33
Oligochaetes (unidentified)	1470	815	1143	13.23	42.56
Mediomastus ambiseta	723	166	445	5.15	47.70
Sphaerosyllis sp. A	605	226	416	4.81	52.52
Haploscoloplos foliosus	401	308	355	4.10	56.62
Capitella capitata	439	161	300	3.47	60.09
Syllis cornuta	243	355	299	3.46	63.55
Tellina tampaensis	172	335	254	2.94	66.49
Cerithium lutosum	355	147	251	2.90	69.39
Leptochelia rapax	371	8	190	2.19	71.59
Brania furcelligera	63	311	187	2.16	73.75
Laeonereis culveri	243	98	170	1.97	75.72
Anomalocardia auberiana	44	267	155	1.80	77.52
Branchioasychis americana	101	166	134	1.55	79.07
Nemertinea (unidentified)	52	161	106	1.23	80.30
Spiorbis sp.	158	46	102	1.18	81.48
Laevicardium mortoni	3	202	102	1.18	82.67
Dominant species	18	18	18	13.53	
Dominant abundance	8239	6044	7141	82.67	
Other species	81	75	115	86.47	
Total species	99	93	133	100.00	
Total abundance	9475	7836	8655	100.00	

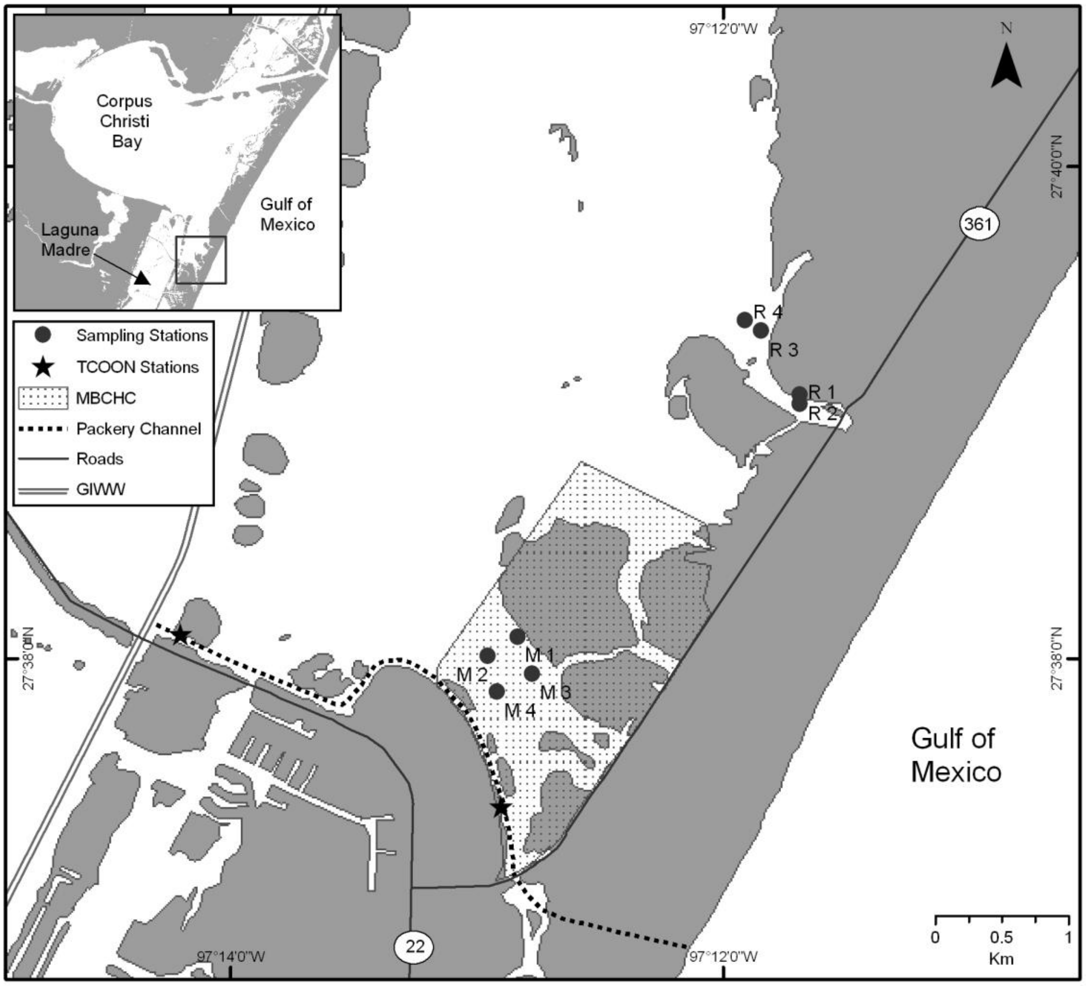

Figure 1. Locations and names of sampling stations. MBCHC = Mollie Beattie Coastal Habitat Community.

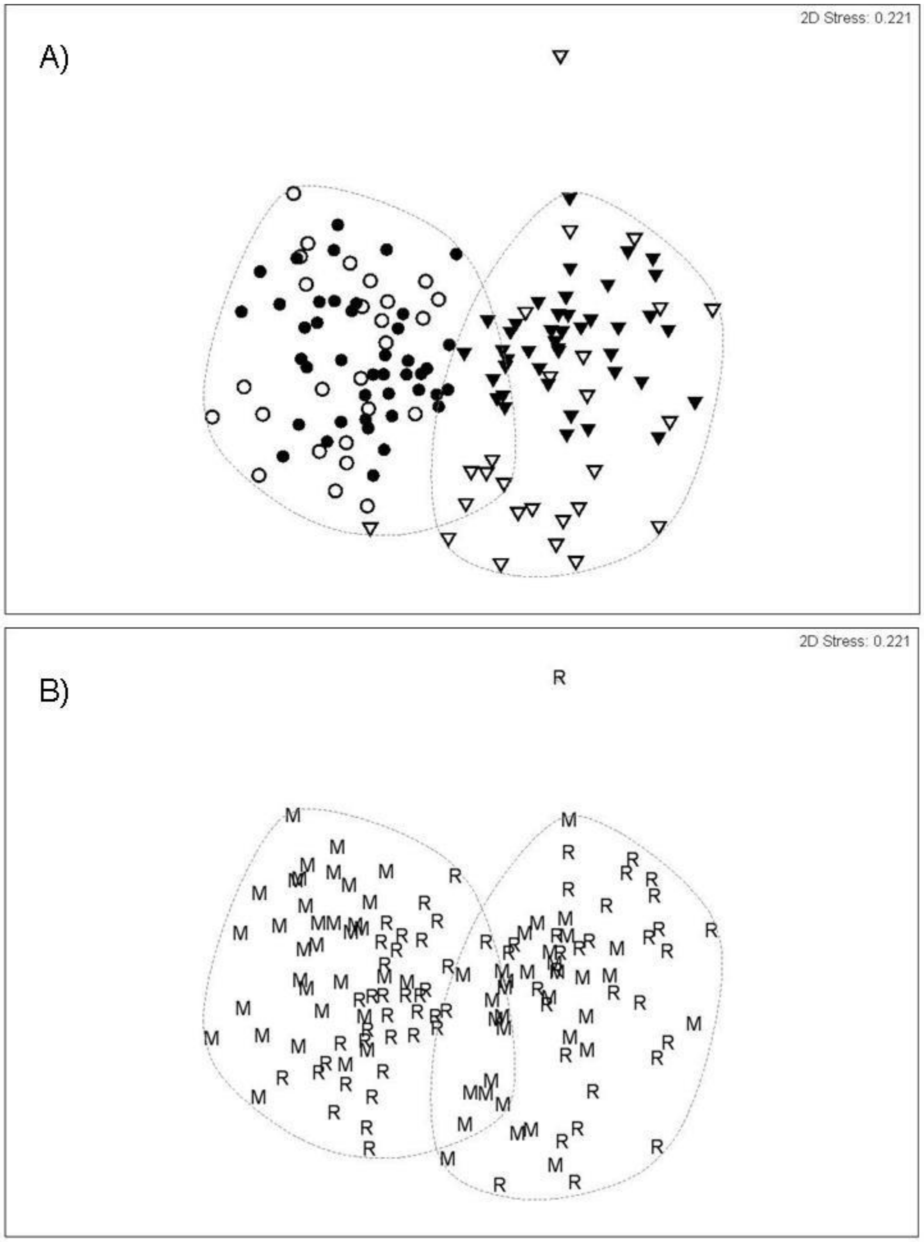

Figure 2. Non-metric multidimensional scaling (MDS) plot with cluster analysis overlay based on log transformed macrofauna species abundances for each date-depth combination at each site. Symbols: solid line = 20 % similarity, dashed line = 30 % similarity. Symbols A: triangles = shallow, circle = deep, closed symbol = channel closed, open symbol = channel open. B: M = Mollie Beattie Coastal Habitat Community site, R = reference site.

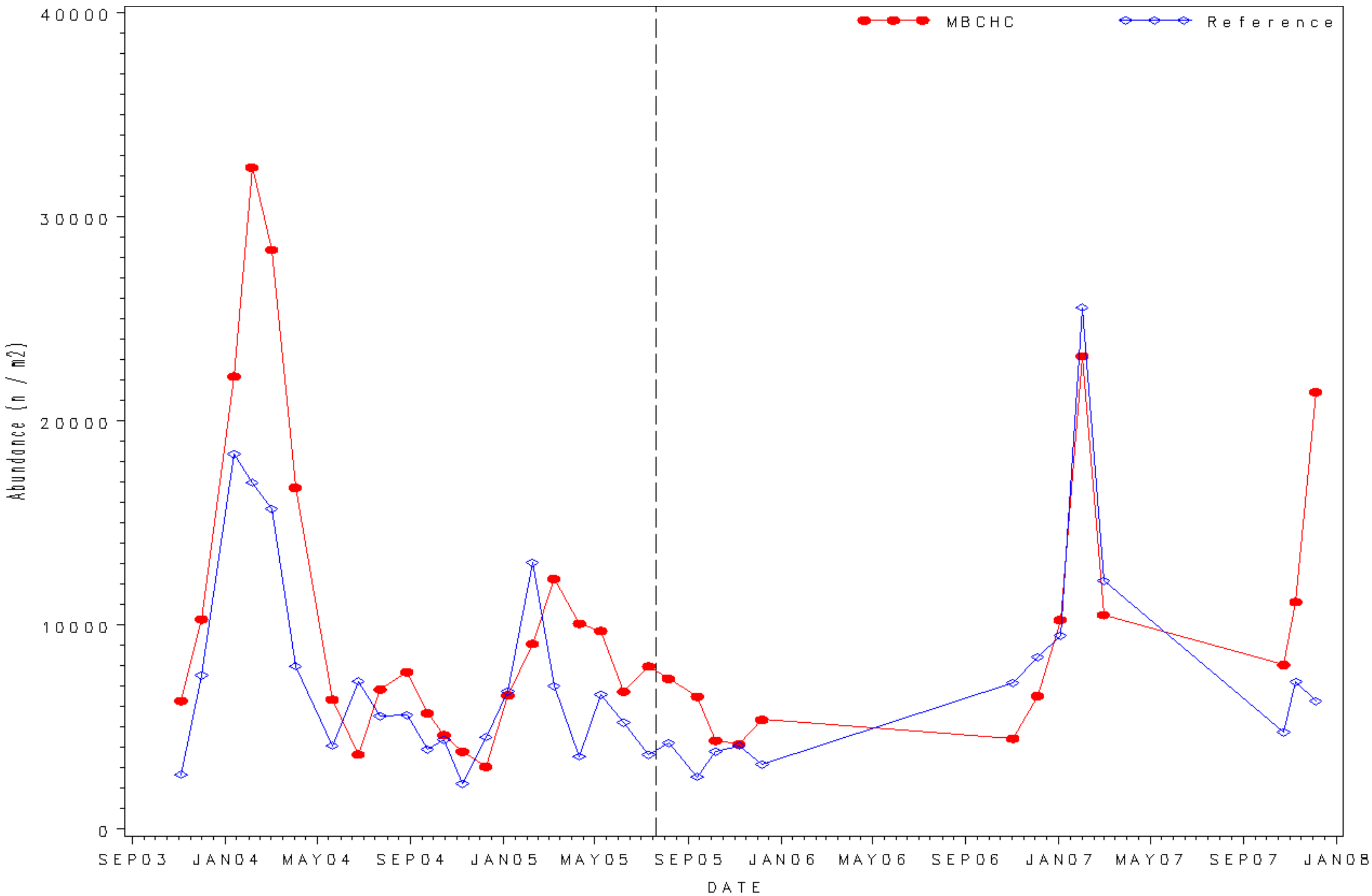

Figure 3. Mean macrofauna abundance at Mollie Beattie Coastal Habitat Community (MBCHC) and Corpus Christi Pass (Reference).

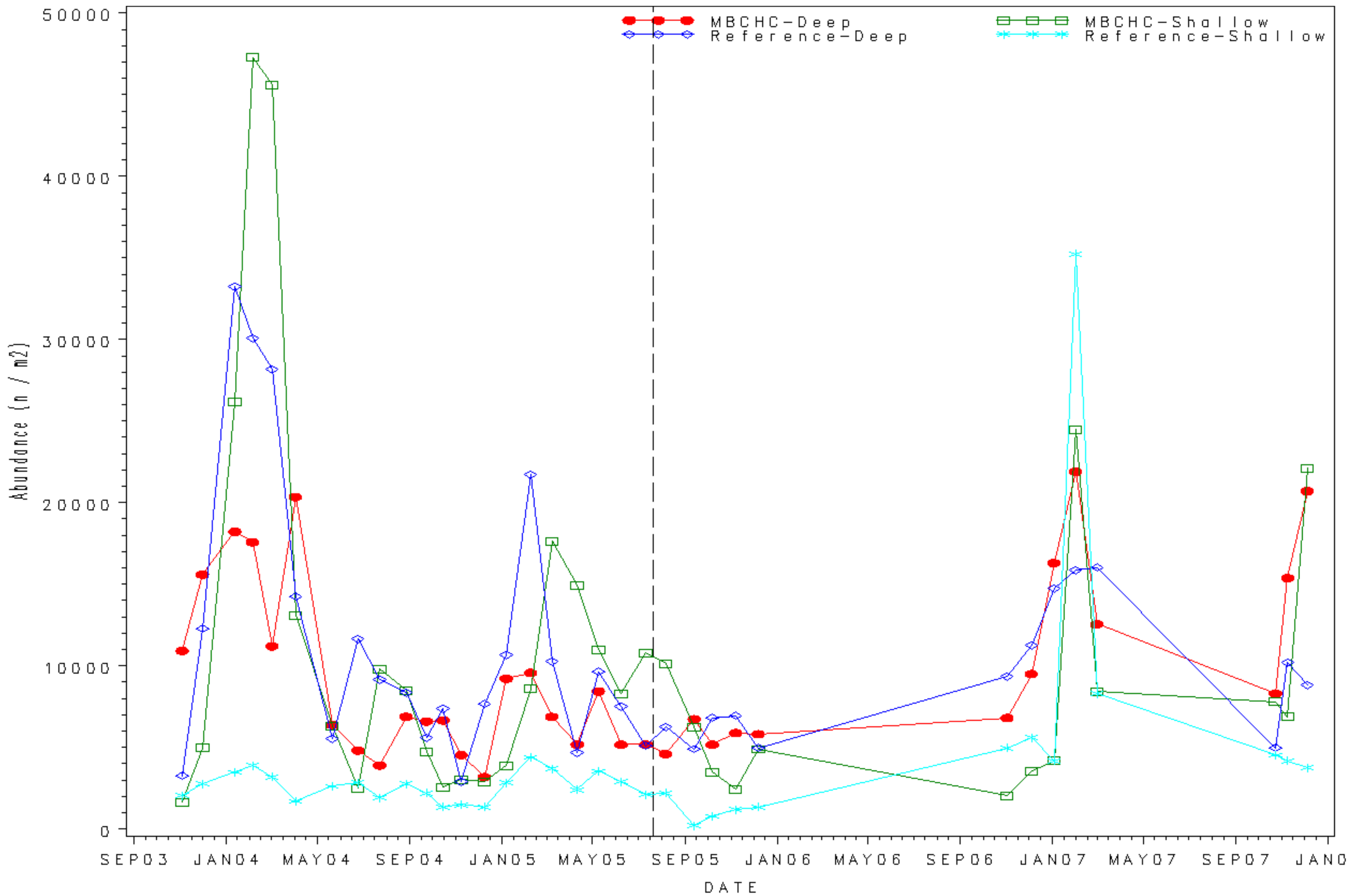

Figure 4. Mean macrofauna abundance at shallow and deep stations in both Mollie Beattie Coastal Habitat Community (MBCHC) and Corpus Christi Pass (Reference).

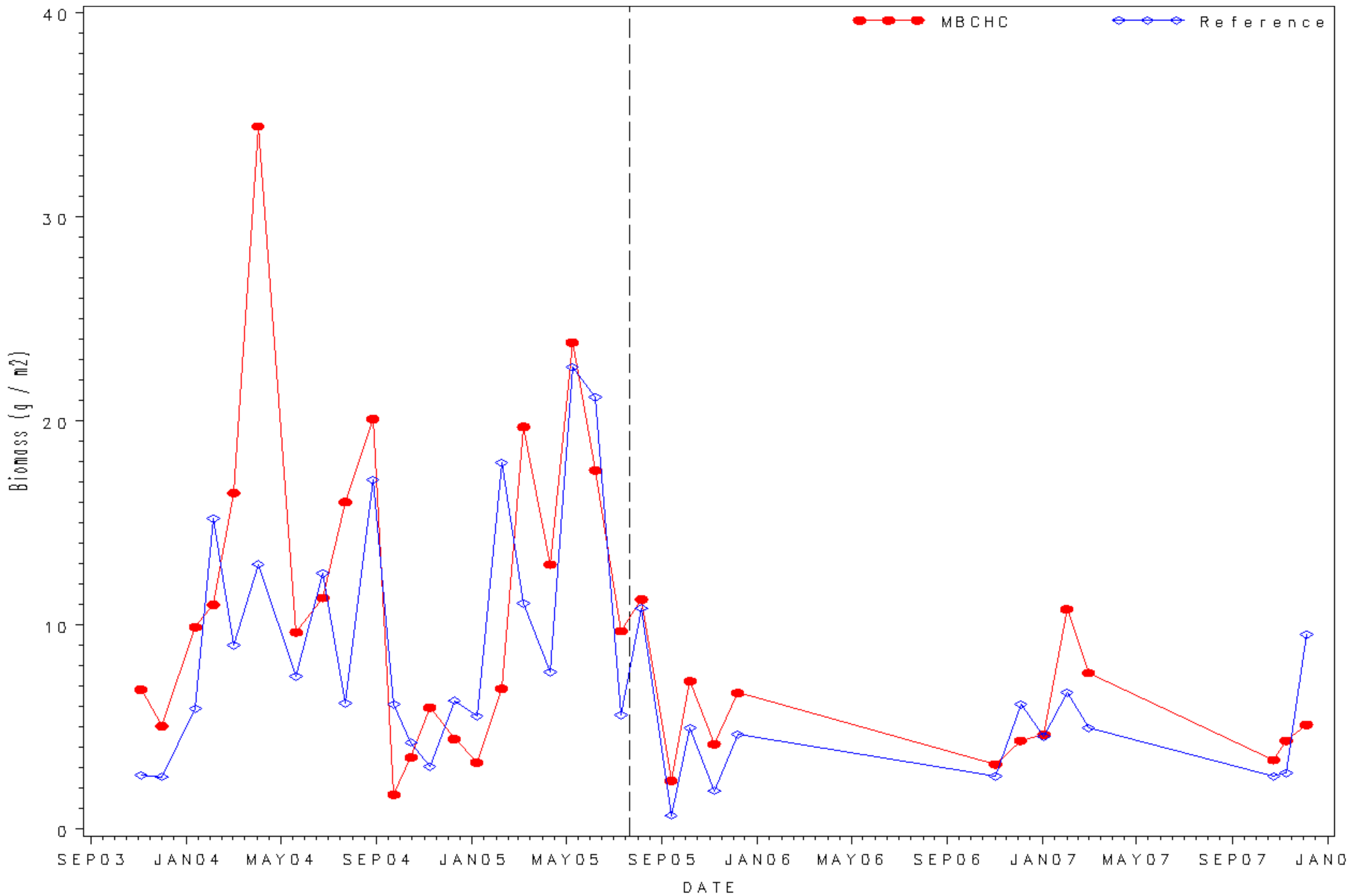

Figure 5. Mean macrofauna biomass at Mollie Beattie Coastal Habitat Community (MBCHC) and Corpus Christi Pass (Reference).

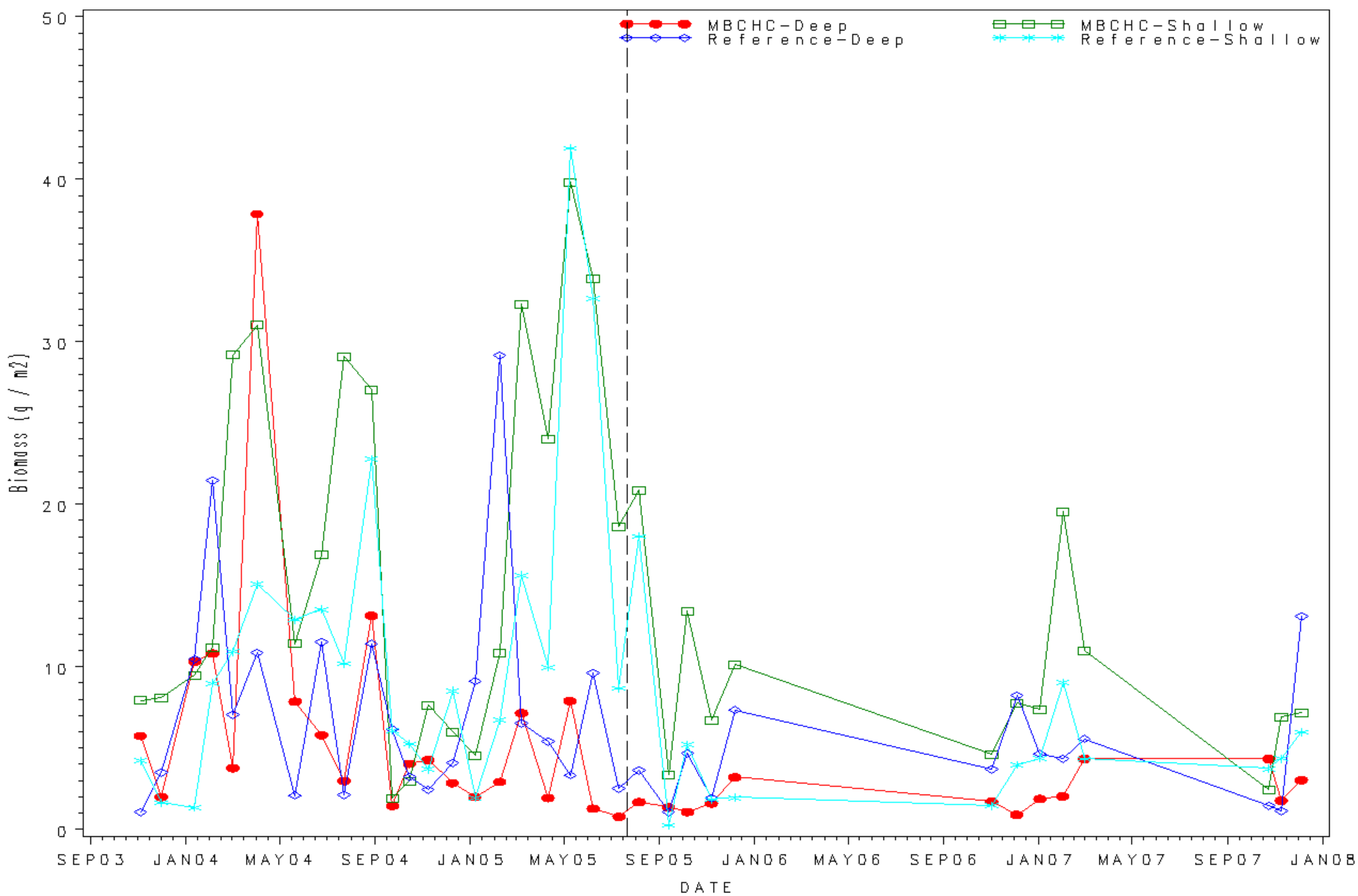

Figure 6. Mean macrofauna biomass at shallow and deep stations in both Mollie Beattie Coastal Habitat Community (MBCHC) and Corpus Christi Pass (Reference).

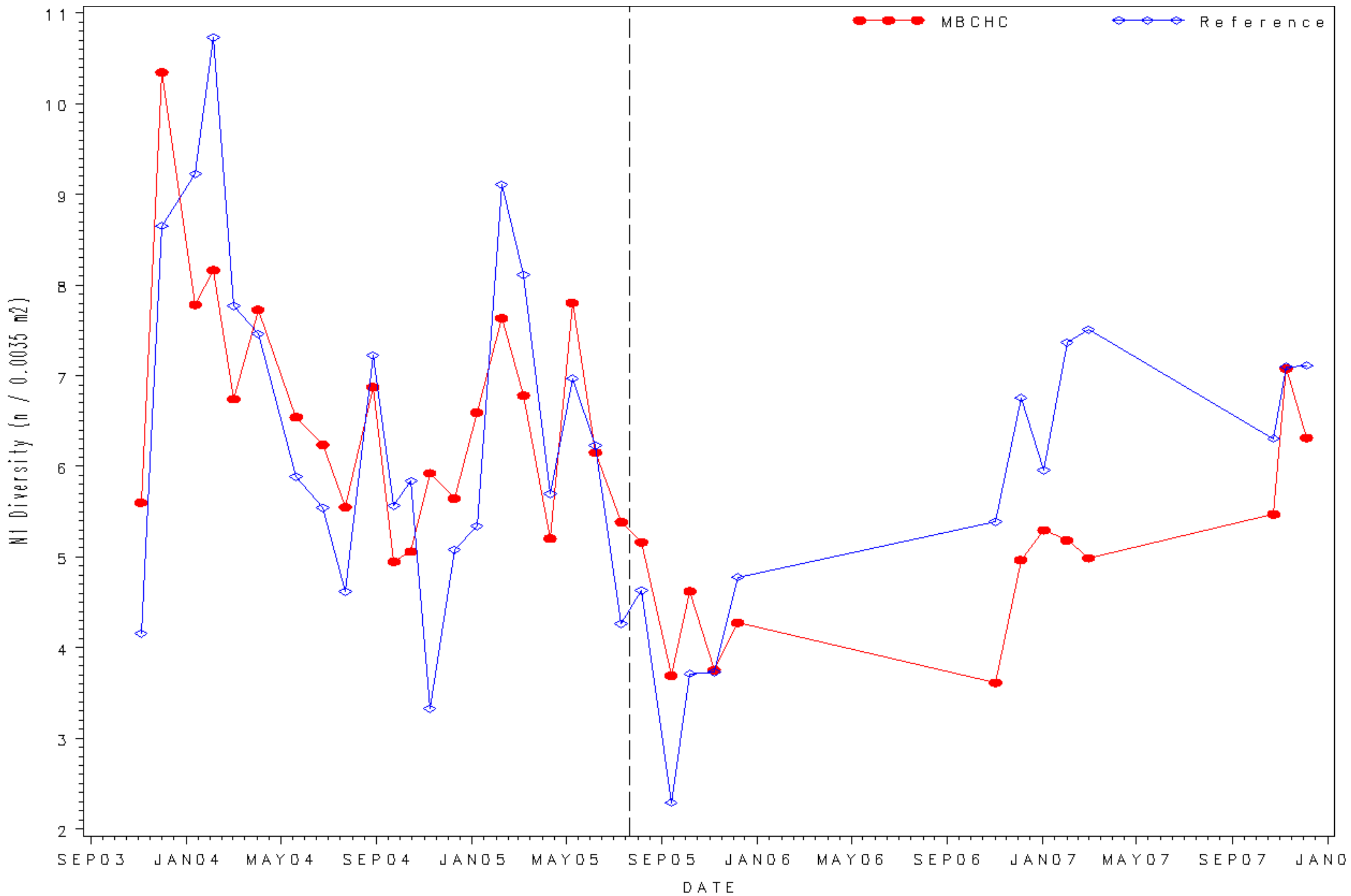

Figure 7. Mean N1 diversity at Mollie Beattie Coastal Habitat Community (MBCHC) and Corpus Christi Pass (Reference).

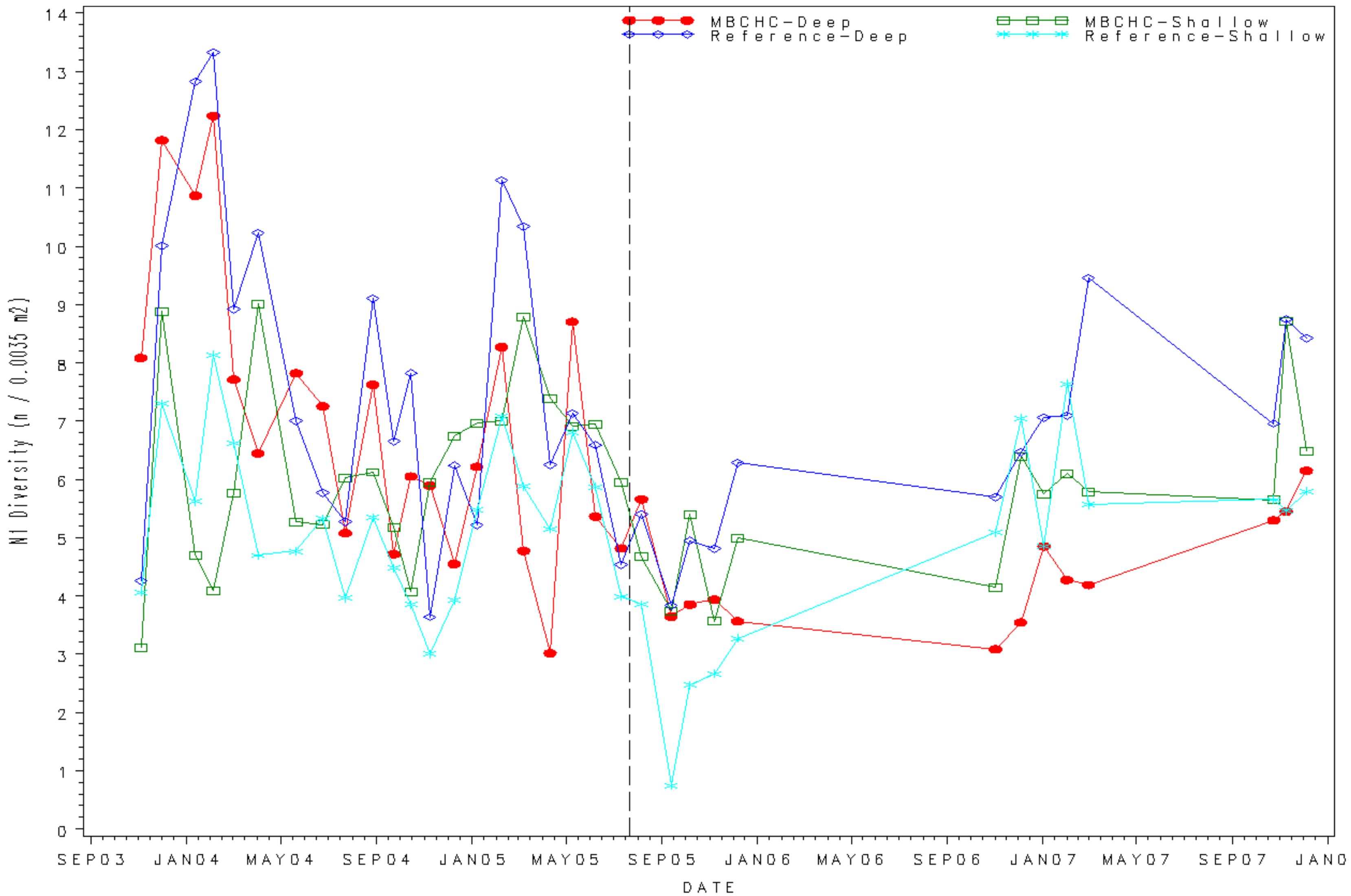

Figure 8. Mean N1 diversity at shallow and deep stations in both Mollie Beattie Coastal Habitat Community (MBCHC) and Corpus Christi Pass (Reference).

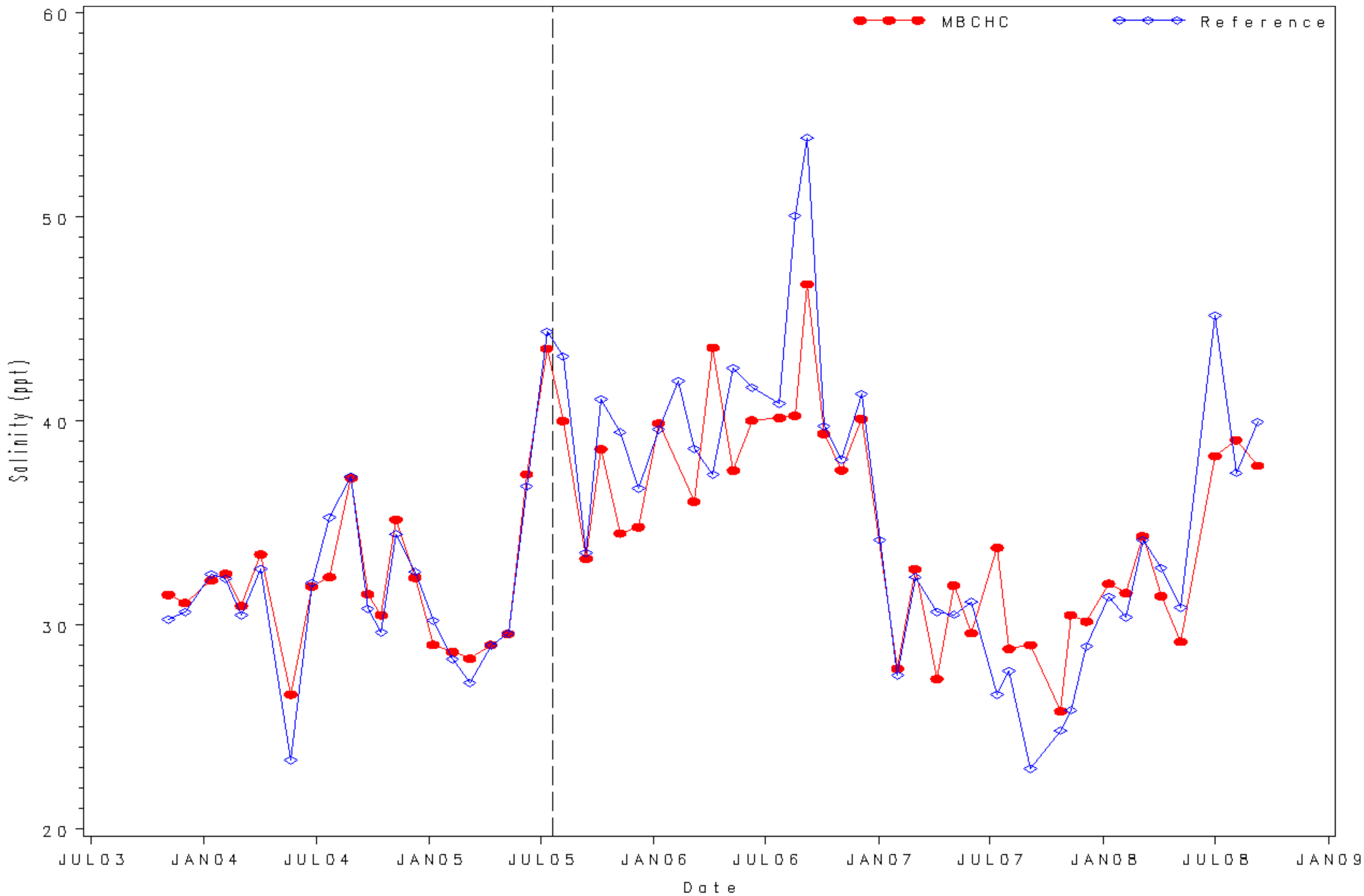

Figure 9. Mean salinity at Mollie Beattie Coastal Habitat Community (MBCHC) and Corpus Christi Pass (Reference).

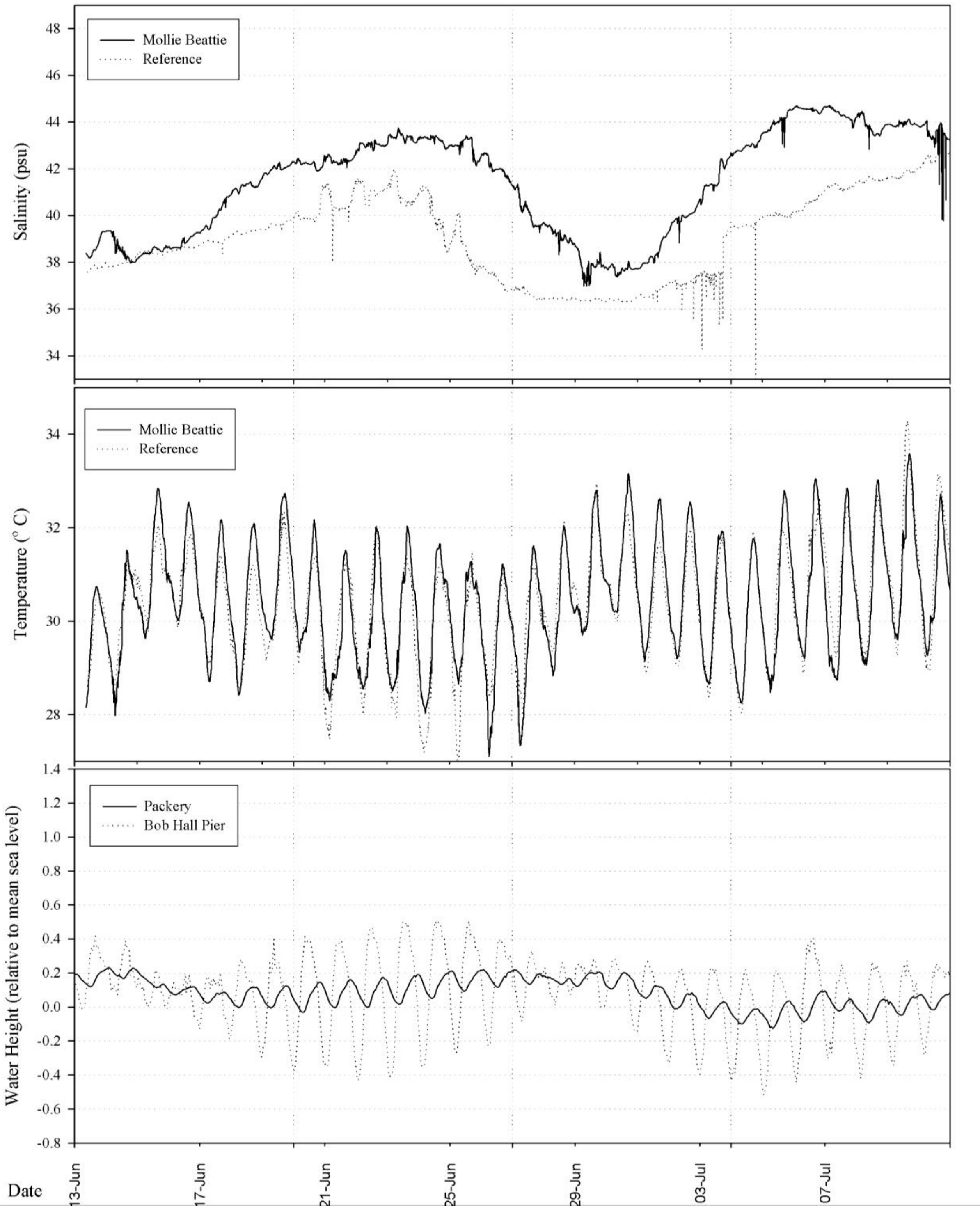

Figure 10. Salinity, temperature and water level in study area in June and July 2005. Salinity and temperature measurements were taken at stations M2 and R4, for Mollie Beattie Coastal Habitat Community (MBCHC) and reference sites respectively. Water level measurements were taken from the nearest water level recorders in the Gulf of Mexico (Bob Hall Pier) and the Laguna Madre end of Packery Channel. Water level values were taken from TCOON (http://lighthouse.tamucc.edu).

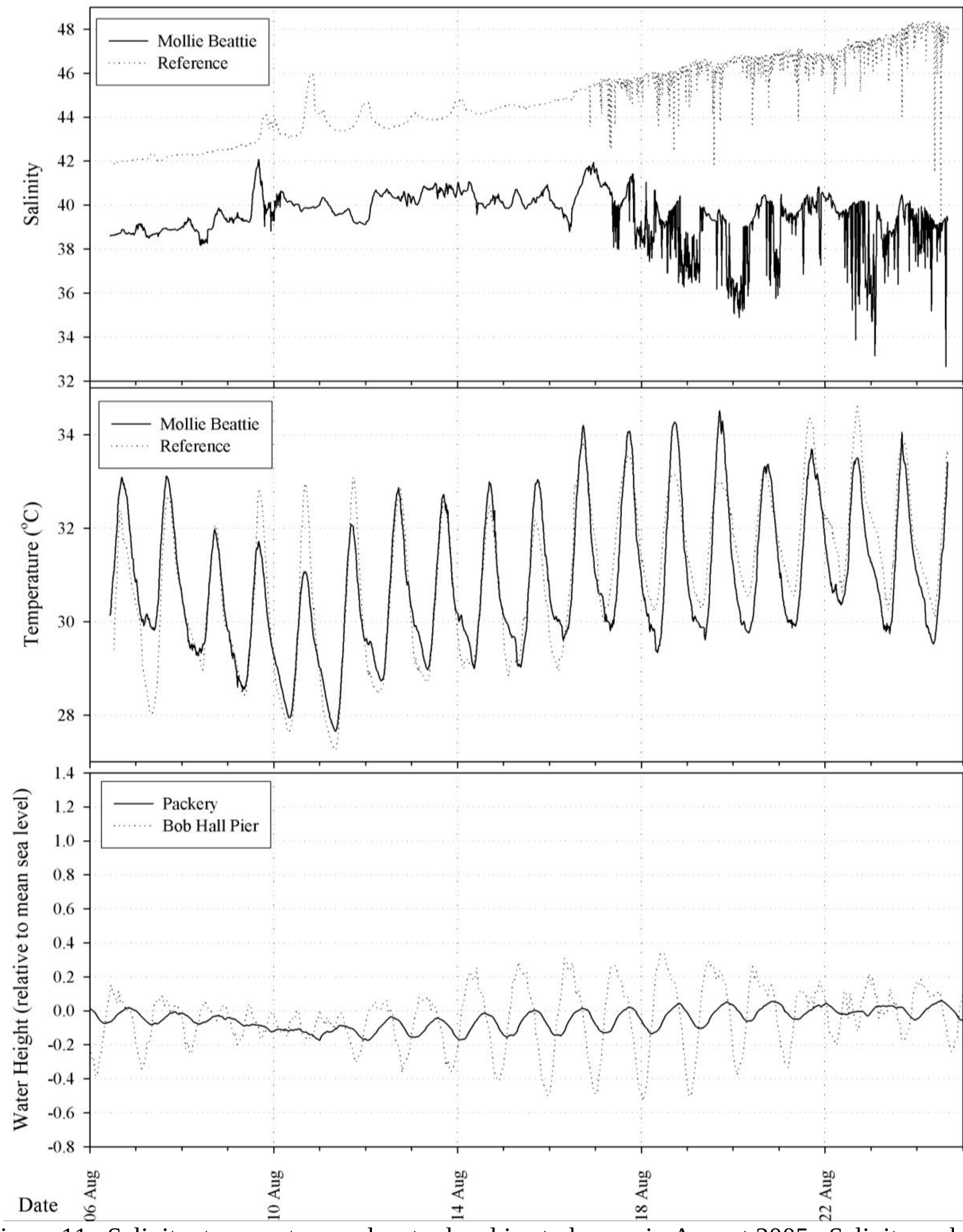

Figure 11. Salinity, temperature and water level in study area in August 2005. Salinity and temperature measurements were taken at stations M2 and R4, for Mollie Beattie Coastal Habitat Community (MBCHC) and reference sites respectively. Water level measurements were taken from the nearest water level recorders in the Gulf of Mexico (Bob Hall Pier) and the Laguna Madre end of Packery Channel. Water level values were taken from TCOON (http://lighthouse.tamucc.edu).

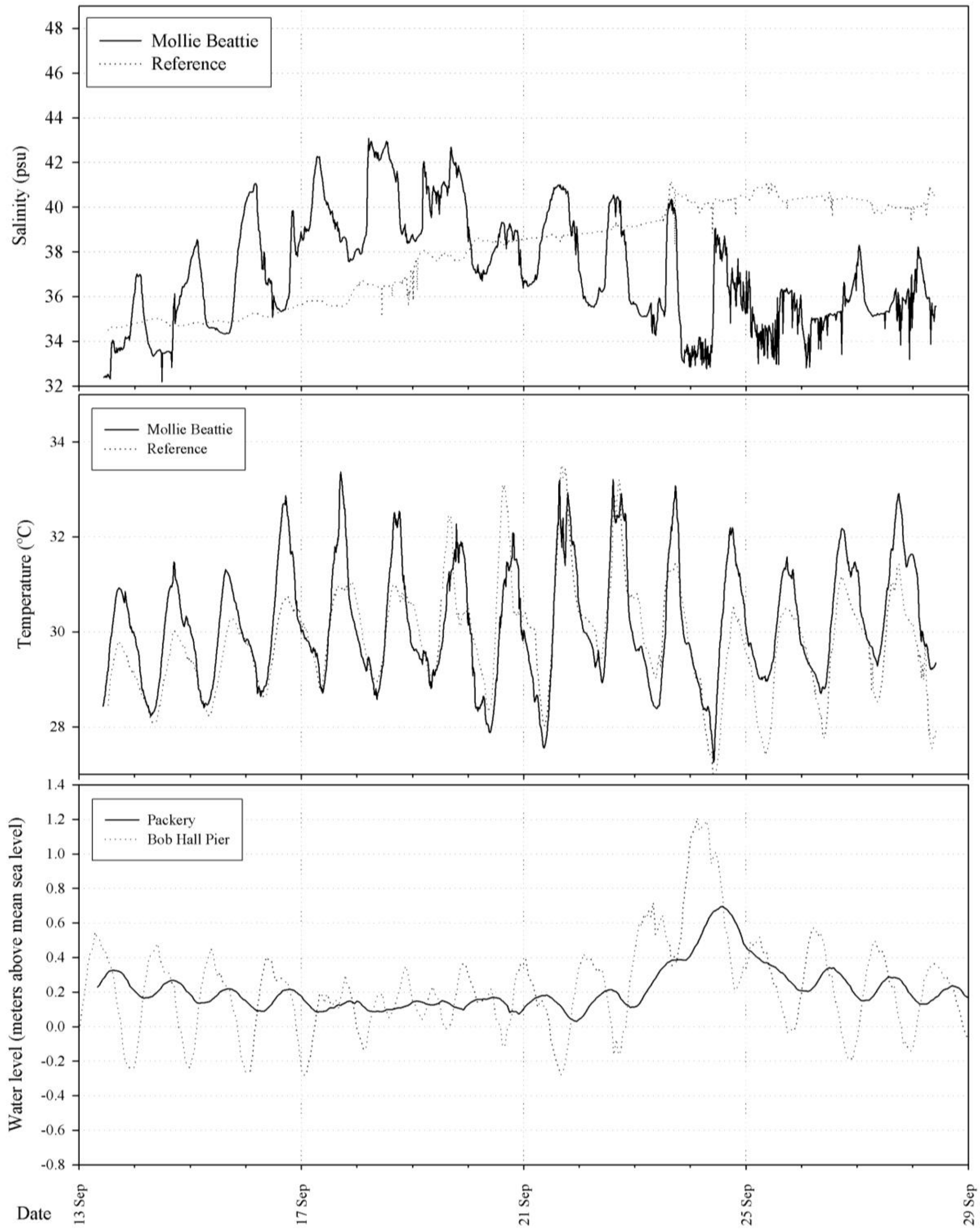

Figure 12. Salinity, temperature and water level in study area in September 2005. Salinity and temperature measurements were taken at stations M2 and R4, for Mollie Beattie Coastal Habitat Community (MBCHC) and reference sites respectively. Water level measurements were taken from the nearest water level recorders in the Gulf of Mexico (Bob Hall Pier) and the Laguna Madre end of Packery Channel. Water level values were taken from TCOON (http://lighthouse.tamucc.edu).